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The Relation between Star Colours and Spectra.

By W. S. Franks.

In a former paper on this subject (*Monthly Notices*, June 1907) I gave the result of an investigation into the relation between the colours and spectra of 1360 bright stars, in both hemispheres; the colours depending on the observations made by members of the British Astronomical Association in England and Australia. The stars observed in this country, from the N. pole to 25° south declination, amounted to 928 of the total number. The recent publication of the *Revised Harvard Photometry*, which contains over 9000 stars down to 6½ magnitude, has enabled me to carry this inquiry a stage further. Making use only of my own colour observations, contained in a MS. synoptic catalogue of 4175 stars (which includes *all* my previous work in this direction), I have carefully compared this with the Harvard revised spectra. The number of stars between the N. pole and −25°, common to both lists, amounts to 3497; which is nearly four times greater than the B.A.A. total, and it includes stars down to 6½ magnitude. As the colour estimates in my earlier catalogues were not expressed by symbols, like the B.A.A. and my later observations, I have used the old notation in this paper—dividing the colours into seven groups, as here shown :—

				Symbol.
1.	White	Stars	—including bluish-white and greenish-white . .	O
2.	Yellowish White	,,	—an important and well-marked class . . .	Y^1
3.	Pale Yellow	,,	—including a few pale orange-yellow . . .	Y^2
4.	Yellow	,,	—(normal tint) including orange yellow and full yellow	Y^3
5.	Pale Orange	,,	—a distinctive group	Or^2
6.	Orange	,,	—(normal tint) including also full orange . .	Or^3
7.	Orange Red	,,	—including all ruddy tints	OrR^3

The foregoing colours are distributed as follows :—

	Colour.	Number.	Percentage.
1.	White	1083	31·0
2.	Yellowish White	729	20·8
3.	Pale Yellow	782	22·4
4.	Yellow	413	11·8
5.	Pale Orange	271	7·7
6.	Orange	195	5·6
7.	Orange Red	24	0·7
	Total	3497	100·0

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Analysis of Colours and Spectra.

TABLE I.

Colour.	Od	Oe	Oe5B	B	B1A	B2A	B3A	B4A	B5A	B8A	B9A	A	A2F	A3F	A4F	A5F	A8F
White	...	...	5	23	9	22	88	...	49	69	21	605	79	18	1	28	2
Yelsh. Wh.	...	...	4	3	8	10	11	1	17	13	10	254	41	20	...	63	2
Pale Yell.	1	1	1	...	...	...	1	...	...	3	2	38	12	4	...	13	1
Yellow	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Pale Orange	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Orange	...	...	...	...	...	...	...	...	...	...	...	..	...	...	...	...	...
Orange Red	...	...	...	...	...	...	...	...	...	...	...	...	...	..	...	...	...
Total	1	1	10	26	17	32	100	1	66	85	33	897	132	42	1	104	5

(continued below.)

Colour.	F	F2G	F5G	F7G	F8G	G	G2K	G5K	G8K	K	K2M	K5M	Ma	Mb	Mc	Md	N	Total.
White	44	4	7	...	2	7	...	...	...	...	...	...	...	...	...	...	...	1083
Yelsh. Wh.	134	5	47	1	18	37	3	10	...	17	...	...	...	...	...	...	...	729
Pale Yell.	110	19	51	1	36	102	15	88	...	260	2	10	8	3	...	...	...	782
Yellow	8	1	4	...	6	22	4	35	1	274	7	25	20	6	...	...	...	413
Pale Orange	...	...	2	...	1	13	3	24	...	155	2	27	30	14	...	...	...	271
Orange	...	...	...	...	...	2	2	9	...	84	3	33	45	12	1	1	3	195
Orange Red	...	...	...	...	...	...	...	2	...	4	...	...	6	1	...	3	8	24
Total	296	29	111	2	63	183	27	168	1	794	14	95	109	36	1	4	11	3497

Summary of Analysis.

TABLE II.

Group.	Spectrum Type.	White.	Yelsh. Wh.	Pale Yel.	Yellow.	Pale Or.	Orange.	Orange Red.	Total.
Od and Oe	Bright line spectra	...	...	2	...	...	...	...	2
Oe5B	Intermediate	5	4	1	...	...	...	...	10
B to B5A	Orion type	191	50	1	...	...	...	...	242
B8A ,, A4F	Sirius ,,	793	338	59	...	...	...	...	1190
A5F ,, F2G	α Carinæ ,,	78	204	143	9	...	...	...	434
F5G	Procyon ,,	7	47	51	4	2	...	...	111
F7G to G8K	Capella ,,	9	69	242	68	41	13	2	444
K	Arcturus ,,	...	17	260	274	155	84	4	794
K2M and K5M	Aldebaran ,,	...	...	12	32	29	36	...	109
Ma to Md	Betelgeuse ,,	...	...	11	26	44	59	10	150
N	19 Piscium ,,	...	...	...	...	...	3	8	11
	Total	1083	729	782	413	271	195	24	3497

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Percentage of Colours in each Group.

TABLE III.

Group.	White.	Yelsh. Wh.	Pale Yel.	Yellow.	Pale Or.	Orange.	Orange Red.	Total.
Od and Oe	...	...	100·0	...	...	...	...	100·0
Oe5B	50·0	40·0	10·0	...	...	...	..	100·0
B to B5A	78·9	20·7	0·4	...	...	...	...	100·0
B8A ,, A4F	66·6	28·4	5·0	...	...	...	...	100·0
A5F ,, F2G	18·0	47·0	33·0	2·0	...	...	...	100·0
F5G	6·3	42·3	46·0	3·6	1·8	...	...	100·0
F7G to G8K	2·0	15·5	54·5	15·3	9·2	3·0	0·5	100·0
K	...	2·1	32·8	34·5	19·5	10·6	0·5	100·0
K2M and K5M	...	...	11·0	29·4	26·6	33·0	...	100·0
Ma to Md	...	...	7·3	17·3	29·3	39·4	6·7	100·0
N	...	...	...	...	...	27·3	72·7	100·0

Classification of Spectra in Tables II. and III.

Photo. Spectra.				Visual Spectra
Oa to Oe	—Bright line spectra		=	V.
Oe5B	—All dark lines (intermediate between O and B)		=	V–I.
B to B5A	—Helium ,, Orion type	B . .	=	I*a*.
B8A to A3F	—Hydrogen ,, Sirius ,,	A . .	=	I*b*.
A5F to F2G	— do. ½ intensity *a* Carinæ ,,	F . .	=	I–II*a*.
F5G	— (Intermediate) Procyon ,,	F5G . .	=	I–II*b*.
F8G to G5K	— Solar lines Capella ,,	G . .	=	II.
K	— "K" line intense Arcturus ,,	K . .	=	II–III*a*.
K2M and K5M	— (Intermediate) Aldebaran ,,	K5M . .	=	II–III*b*.
Ma to Md	— Banded spectra Betelgeuse ,,	Ma . .	=	III.
N	— do. (reversed) 19 Piscium ,,	N (ruddy stars)	=	IV.

The last class (N) would be considerably increased but for the difficulty of photographing objects near the red end of spectrum—hence they fall short of the number that can be observed visually. A number of red and orange stars of 6½ magnitude, contained in my catalogue, are, from this cause, entirely omitted from the Harvard spectra results.

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Deductions from preceding Tables.

Spectrum	O—	*Maximum*	in white, gradually decreasing to pale yellow.
,,	B—	,,	,, ,, (practically 79 per cent.). The *whitest* stars.
,,	A—	,,	also ,, but less wh. and more yelsh. wh. than B.
,,	F—	,,	,, yelsh. white, but the pale yellow not far behind.
,,	F5G—	,,	between yelsh. wh. and pale yel.—the latter slightly in excess.
,,	G—	,,	in pale yellow—very pronounced.
,,	K—	,,	between pale yel. and yellow—nearly equal.
,,	K2M and K5M	,,	pretty evenly distributed between yel., pale or., and orange.
,,	M—	,,	in orange, but pale orange not far behind.
,,	N—	,,	orange red—very pronounced.

The *sequence* of *colours* corresponding to the *sequence* of the *spectra* is thus unmistakably indicated. But in the A class there is a definite number of pale yellow stars; their occurrence is too frequent and regular to be accidental; they show an increase in frequency in the regions where coloured stars are predominant. Likewise there is a still larger fraction of white stars in the F class—contrary to the normal. This serves to emphasise the fact that in some cases two stars of exactly the same colour visually are of different spectral types—some noteworthy examples of which have come to light during the present investigation. And, conversely, some stars of identical spectra differ very perceptibly in colour—whatever the cause of such discrepancy may be. But perhaps these exceptions, which after all are not very numerous, merely point the rule which governs the relation between colour and spectrum in the great majority of cases. If I have succeeded in establishing this connection, it may be also a plea that star colour observations *do* possess some value; and I shall consider that these thousands of independent estimates, which have so long lain dormant, were not altogether made in vain.

Uxbridge: 1908 *August* 12.

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Note on Y Cephei. By Rev. J. G. Hagen, S.J.

(*Communicated in a letter to the Astronomer Royal.*)

"The advance prints of your Astrographic Plates 3619 and 6983, which you kindly sent me for the examination of Y Cephei and its surroundings, have enabled me to measure the additional stars to the Atlas Chart of this variable which were invisible in the 12-inch refractor. They will be recorded in the Catalogue sheet No. 188 of series vi., with due acknowledgment.

"Since the magnitudes of this series are all reduced to the Harvard scale, it is well to put the magnitudes of Y Cephei, as shown on your plates, on record for future corrections of the elements of variation. The following extract from the Catalogue will designate four comparison stars:—

	m s	′	m	
No. 3.	$\Delta\alpha = -0\ 20$	$\Delta\delta = -11{\cdot}5$	H.P. 8·7	letter c
4.	,, +3 20	,, −12·1	,, 8·8	,, d
37.	,, 0 0	,, −1·5	,, 12·7	,, ϕ
40.	,, +0 30	,, −1·0	,, 13·1	,, τ

Your plates give the following estimates, which anyone can verify:—

Pl. 3619,	1897 Sept. 9:	c2Y4d,	Magn. 8·7 H.P.
,, 6983,	1908 Jan. 12:	ϕ4Y1τ,	,, 13·0 ,,

"The provisional elements of variation give the following corresponding epochs of maxima:—

Max. 1897 Sept. 24 = Plate 3619 + 15 days.
,, 1907 Nov. 26 = ,, 6983 − 47 days.

"The first plate agrees well with the computed maximum and with the remark of Ceraski (*A.N.* 3644) that the brightness of Y was diminishing in October 1897. The second plate, however, will probably demand a correction to the assumed elements (*A.N.* 3744 and *V.J.S.* 41, page 317), as it is unlikely that the star should have diminished in brightness by $4\frac{1}{2}$ magnitudes in 47 days."

Rome: July 22, 1908.